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Broadband Ultrasonic and Rheological Characterization of Liquids Using Longitudinal Waves

Authors : M. Abderrahmane Mograne, Didier Laux, Jean-Yves Ferrandis

Abstract : Rheological characterizations of complex liquids like polymer solutions present an important scientific interest for a lot of researchers in many fields as biology, food industry, chemistry. In order to establish master curves (elastic moduli vs frequency) which can give information about microstructure, classical rheometers or viscometers (such as Couette systems) are used. For broadband characterization of the sample, temperature is modified in a very large range leading to equivalent frequency modifications applying the Time Temperature Superposition principle. For many liquids undergoing phase transitions, this approach is not applicable. That is the reason, why the development of broadband spectroscopic methods around room temperature becomes a major concern. In literature many solutions have been proposed but, to our knowledge, there is no experimental bench giving the whole rheological characterization for frequencies about a few Hz (Hertz) to many MHz (Mega Hertz). Consequently, our goal is to investigate in a nondestructive way in very broadband frequency (A few Hz – Hundreds of MHz) rheological properties using longitudinal ultrasonic waves (L waves), a unique experimental bench and a specific container for the liquid: a test tube. More specifically, we aim to estimate the three viscosities (longitudinal, shear and bulk) and the complex elastic moduli (M*, G* and K*) respectively longitudinal, shear and bulk moduli. We have decided to use only L waves conditioned in two ways: bulk L wave in the liquid or guided L waves in the tube test walls. In this paper, we will present first results for very low frequencies using the ultrasonic tracking of a falling ball in the test tube. This will lead to the estimation of shear viscosity from a few mPa.s to a few Pa.s (Pascal second). Corrections due to the small dimensions of the tube will be applied and discussed regarding the size of the falling ball. Then the use of bulk L wave's propagation in the liquid and the development of a specific signal processing in order to assess longitudinal velocity and attenuation will conduct to the longitudinal viscosity evaluation in the MHz frequency range. At last, the first results concerning the propagation, the generation and the processing of guided compressional waves in the test tube walls will be discussed. All these approaches and results will be compared to standard methods available and already validated in our lab.

Keywords : nondestructive measurement for liquid, piezoelectric transducer, ultrasonic longitudinal waves, viscosities
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